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7. Abstract

Radioactive wastes stored in single shell underground storage tanks (SST's) at Hanford will eventually be retrieved for final disposal. To support retrieval technology development, feature testing will be performed on an ongoing basis either on site or at vendor's locations depending on cost and schedule considerations. Testing will use a simulated waste. The simulant will be made from non-radioactive/non-hazardous materials.

The objective of feature testing is to complement the Engineering Study in recommending technologies for further development. Basic comparative functional testing of the technologies recommended by the study will be done. These will be hands on type tests, however eventually the equipment will be employed in remote, hostile environments

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SINGLE-SHELL TANK WASTE RETRIEVAL

EQUIPMENT FEATURE TEST PLAN

1.0 INTRODUCTION

The Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement) was signed in May of 1989 by the Washington State Department of Ecology, the United States Environmental Protection Agency, and the United States Department of Energy. The purpose of the Tri-Party Agreement document is to provide the framework for "ensuring that the environmental impacts associated with past and present activities at Hanford Site are thoroughly investigated and appropriate response action taken as necessary to protect the public health, welfare and the environment."

Milestones in the Tri-Party Agreement Action Plan call for development of technologies for retrieving single-shell tank waste. This document describes the program for feature testing of equipment to support the completion of Tri-Party Agreement milestones M-06-00 and M-07-00. Milestone M-06-00, (June 1994) represents the completion of all technology development required for waste retrieval. Milestone M-07-00 (October 1997) is the initiation of waste retrieval from a single-shell tank.

Feature testing will be performed on an ongoing basis either on site or at vendor's locations depending on cost and schedule considerations. Testing will use a simulated waste. The simulant will possess only those properties necessary for this comparison. It will also be nonhazardous, easily transported, economical, and made from commercially available materials. As this test is a coarse filter of technologies, it is not important that the simulant emulate all waste parameters with high accuracy. Two or more simulant formulas will be developed, based on the necessary parameters, with at least one for sludge and one for salt cake.

The initial series of feature tests are shown in Table 1, Section 4.0 of this document.

2.0 OBJECTIVES

The objective of Feature Testing is to complement the Engineering Study in recommending technologies for further development. Basic comparative functional testing of the technologies recommended by the study will be done using simulated waste. These will be hands on type tests; however, eventually the equipment will be employed in remote, hostile environments.

This comparative test will investigate commercially available technologies for dislodging/conveying the waste and equipment to remove and transfer In-Tank Hardware (ITH). This is a comparative test in which significantly deficient technologies will be gleaned from the viable alternatives. Those technologies exhibiting potential will be carried forward for further testing and development. Therefore not all parameters will be prototypic of final hardware requirements.

Technologies for maneuvering this equipment inside the tank are not included in Feature Testing. This technology will be designed and tested in the Technology Test Unit development phase. This information will also provide a basis for detailed design of demonstration unit hardware.

3.0 SCOPE

The scope of this task is not to optimize parameters, but to evaluate an "off the shelf" technology's feasibility as a waste dislodging/conveying and ITH removing/transporting tool. The outcome of these tests will support the engineering study in recommending technologies for development.

No radioactive or hazardous materials will be used in this testing program.

4.0 DESCRIPTION OF TESTING

The Feature Testing program will be carried out on an ongoing basis. For that reason new testing will be added to the program at the discretion of Westinghouse Hanford Company Engineering. As new testing is identified, a statement of work will be prepared and added to this test plan by revision of the document. Table 1 will show test information such as description, location and who has responsibility for conducting the test. The statement of work will give the detail requirements for the test, and will be added to the appendices of this document.

TABLE 1

DESCRIPTION OF TEST	ON SITE RESPONSIBILITY ORG. CODE	TEST LOCATION BLDG/AREA	REFERENCE APPENDICES
SINE PUMP	N/A	VENDOR	A
WATER/AIR SCARIFIER	N/A	VENDOR	B
AIR CONVEYANCE SYS	23120	427/400	C
PNEUMATIC NEEDLE SCALER	23120	2703/200E	D

4.1 TEST ENVIRONMENT

All feature testing will be done at Westinghouse Hanford facilities or at vendor sites. The decision on testing location will be determined by Westinghouse Hanford Engineering. Westinghouse Hanford engineers will be present during all phases of testing whether they are conducted on site or off site.

4.2 EQUIPMENT AND FACILITIES

Equipment and facilities will be provided by vendors or the selected Westinghouse Hanford Company organization performing the test. Detailed requirements are listed in the statement of work for each test. (See Table 1, Section 4.0)

4.3 SIMULANT DEVELOPMENT

All testing shall be performed using an acceptable simulant which emulates the important parameters. Westinghouse Hanford Company has developed several simulants for use and will develop more as testing requires. (Wong 1990).

4.3.1 Sludge Simulant

The properties of the developed sludge simulants are shown in Table 2.

4.3.2 Salt Cake Simulant

Two forms of salt cake simulant have been developed. Type 1 is hard and dry. Type 2 is a soft, moist material to simulate salt cake saturated in a chemical liquor. The properties of the salt cake simulants are shown in Table 3.

TABLE 2

Sludge Design Parameters

Properties	Undiluted	1:1 Dilution	% Deviation
Bulk Density (g/ml)	1.6	1.1	+/- 15%
Viscosity (cp)	1.7×10^6	40	+/- 15%

TABLE 3

Salt Cake Design Parameters

Properties	Hard Salt Cake	Soft Salt Cake	% Deviation
Bulk Density (g/ml)	2.0	1.1	+/- 15%
Shear Force (lbs)	6000	--	+/- 40%
Penetrometer Test (lbs)*	>200	<10	--

* The penetrometer test will measure the material resistance in pounds using a 0.025 square inch penetrometer head.

4.4 DATA

Data required and specific details of data acquisition for each test are defined in the appendices. (See Table 1, Section 4.0)

4.5 CRITERIA/CONSTRAINTS

Criteria and constraints will be as specified in the test procedures for each testing program. Test procedures will be the responsibility of the Westinghouse Hanford Company organization/vendor preforming the test. For specific details see the appendices. (See Table 1, Section 4.0)

5.0 EXPECTED RESULTS

To be considered successful:

A. The equipment must either dislodge/convey 30 gpm of simulant during steady state operation.

B. The equipment must be able to remove and transport ITH to the surface.

The equipment shall do so without the appearance of equipment abuse and shall not appear to tax the equipments capabilities in such a manner that solutions are limited to technology advances.

Testing can also be considered a success although a throughput of 30 gpm was not achieved, providing equipment can be sized correctly without encroaching on the present technology.

6.0 TEST PROCEDURE

Test procedures for each feature test will be submitted for Westinghouse Hanford engineering approval prior to testing. Procedures will either be written by the selected vendor or the on site testing organization. The test procedures must address all details of testing as specified in the appendices. (See Table 1, Section 4.0).

7.0 SAFETY

It will be the testing organizations responsibility to ensure that all activities about the preparation, completion, and disposition of these activities shall be by local, state, and federal codes, regulations, and guidelines.

8.0 QUALITY ASSURANCE

All feature testing will be performed at Impact Level 4 and no Quality Assurance witness of test results is required.

9.0 ORGANIZATIONAL AND FUNCTION RESPONSIBILITIES

The Remote Systems Engineering Group will provide the role of primary operating group. The Chemical Engineering Laboratory (CEL) of the Chemical Processing Systems Engineering Department will control the formulation of simulant materials for both sludge and salt-cake. The CEL will interface with their own contacts for Safety Engineering, Environmental Assurance, Quality Assurance, and Waste Disposal.

10.0 SCHEDULE

The schedule for completion of feature testing is as follows:

Initial Feature Testing *	9/90
Miscellaneous Additional Testing **	7/91

* To support Tri-Party Agreement milestone M-06-01, (10/90).

**This date may change due to scheduling demands.

11.0 REPORTS

A data summary will be issued by the testing organization/vendor. An interim test report may be issued to release testing data and engineering conclusions. The results of the feature testing will be issued as a supporting document test report which will include test procedures, data summaries, and engineering conclusions/recommendations.

A numbered engineering log book will maintained for all feature testing. Problem areas along with their resolutions shall be documented in the log.

12.0 REFERENCES

Krieg, S. A., 1990, *Single-Shell Tank Waste Retrieval Study*, WHC-EP-0352, Westinghouse Hanford Company, Richland, Washington.

13.0 DATA SHEETS

Data sheets will be provided in the test procedures by the vendor/Westinghouse Hanford. Data will include unit, method of measuring.

APPENDIX A

SINE PUMP

STATEMENT OF WORK

STATEMENT OF WORK FOR THE SINE PUMP FEATURE TESTS

1.0 INTRODUCTION

Investigations have identified several methods for the removal of wastes from 149 single-shell waste tanks located at the Hanford Site in southeastern Washington state. One of the potential methods identified is a commercially available sine pump.

The completion of this testing will result in recommending retrieval methods for future development. This document discusses and defines the tasks to be performed to support the testing and evaluation of this technology.

2.0 OBJECTIVE

All feature testing shall be run with one pump, a SINE model SPS-50, using a 15 HP motor. The Type A waste simulant (see Section 4.0) should be pumped at 30 gpm at 125 psig and Type B should be pumped at 60 gpm at 125 psig. The suction head can be varied to evaluate pump performance with the simulant by adjusting the suction valve and reading the suction pressure gauge.

3.0 SCOPE

The scope of this task is not to optimize parameters, but to evaluate the feasibility of an "off the shelf" SINE pump to pump simulated sludge at prescribed flow rates. Actual test results will be compared to seller published statistical data.

4.0 TEST SIMULANT

4.1 SIMULANT DEVELOPMENT

All testing shall be performed using waste simulant developed by Westinghouse Hanford Company. The simulants are still in development and may deviate slightly from the target values as indicated.

4.2 SLUDGE SIMULANT

The primary components of the sludge simulant will be bentonite clay, gravel, water, and barium sulfate (a non-toxic, non-hazardous material). The rock material will simulate sludge chunks. The physical size of the rock will not be greater than specified in the vendor data. The criteria for the sludge simulants are Type A the highest density and viscosity and Type B a 1:1 dilution of sludge Type A. The physical property target values for the two stimulants are as follows:

	Target Values		
Properties	Type A	Type B	Deviation
Bulk Density (g/ml)	1.6	1.3	±15%
Viscosity (cp)	1.7 million	40	±15%

4.3 SIMULANT PROVIDED

Westinghouse Hanford will provide 4 30-gal drums of simulant type A and 8 30-gal drums of simulant Type B .

4.4 SIMULANT RESPONSIBILITIES

4.4.1 Buyer Responsibilities

Westinghouse Hanford will be the generator of record for the simulant when it is declared a waste product. The simulant will have material safety data sheets (MSDS) and will be classified non-hazardous when shipped to the seller. The used test medium will be re-analyzed before disposal to reaffirm its non-hazardous status.

4.4.2 Seller Responsibilities

The seller shall be responsible for the simulants while they are at the seller's test site. This includes assuring that the materials are not chemically contaminated or replaced, and the MSDS are maintained during this period. If the simulants are altered, Westinghouse Hanford Company will not assume disposal responsibility. Containers of waste simulant for this test shall not be opened by the seller until ready for testing and shall be returned to the buyer as received except for the addition of potable water used in cleaning the system.

4.5 TRANSPORTATION/CLEAN-UP

The test simulant will be shipped to the seller's facility, Seattle, Washington just before testing. Each drum shipped will be labeled with a MSDS.

Additional empty Department of Transportation (DOT) approved drums will be sent for use in repackaging of the test simulant. After testing has been completed the simulants shall be cleaned out of the test equipment by the seller. The simulants shall not be altered except for the addition of potable water during the clean-up. The water addition shall be limited to doubling the buyer's furnished test simulant volume.

The simulant shall be repackaged into buyer furnished, DOT approved containers and shipped by the seller to a location directed by Westinghouse Hanford. Westinghouse Hanford Comapny will pay actual shipping costs.

5.0 DESCRIPTION OF TEST

5.1 TEST METHOD

Seller shall prepare a test procedure which, at a minimum, shall cover:

- How testing will be run
- What data will be collected and how
- Schedule for work scope in weeks from purchase order award to completion of data summary
- Detail information on and a schematic of the test loop
- Detail information on pump to be tested

5.2 TEST SET UP

The seller's test loop shall, at a minimum, have:

- Discharge pressure indicator
- A method of measuring pressure/ head loss between pump discharge and the method of varying head loss
- Suction pressure indicator
- A method of varying head loss
- A method of varying suction head
- A method of measuring flow rate
- A way of loading and supplying the test loop with simulant

Figure 1 provides the flow schematic which covers the above listed requirements.

5.3 RECORDING PARAMETERS

The following values shall be recorded by the seller during the feature testing:

- Line pressure at suction of the pump
- Line pressure at discharge of the pump
- Line pressure at discharge of the pump loop immediately upstream of the control valve
- Flow rate of the system
- Motor horsepower
- Pump revolutions per minute
- Pump and loop leakage (visual)
- Simulant temperature
- Voltage reading at the motor
- Amps draw at the motor

The seller should test and record any other parameter they deem pertinent at no additional cost to the buyer.

During each test run the seller shall provide an in plant, on-site SINE Co. field engineer to support the total test program.

In the first test run each simulant shall be tested by the seller at 125 psi discharge pressure and a prescribed discharge flow rate (see Section 2.0). The first test run shall vary the suction pressure from no restriction to a minus 10 psi in 2 psi intervals or until the pump stops pumping whichever comes first.

The second test shall vary the pump RPM from zero to the maximum RPM in 50 RPM steps and record data per section 5.3. This is to be done with each simulant at a fixed discharged pressure of 125 psi.

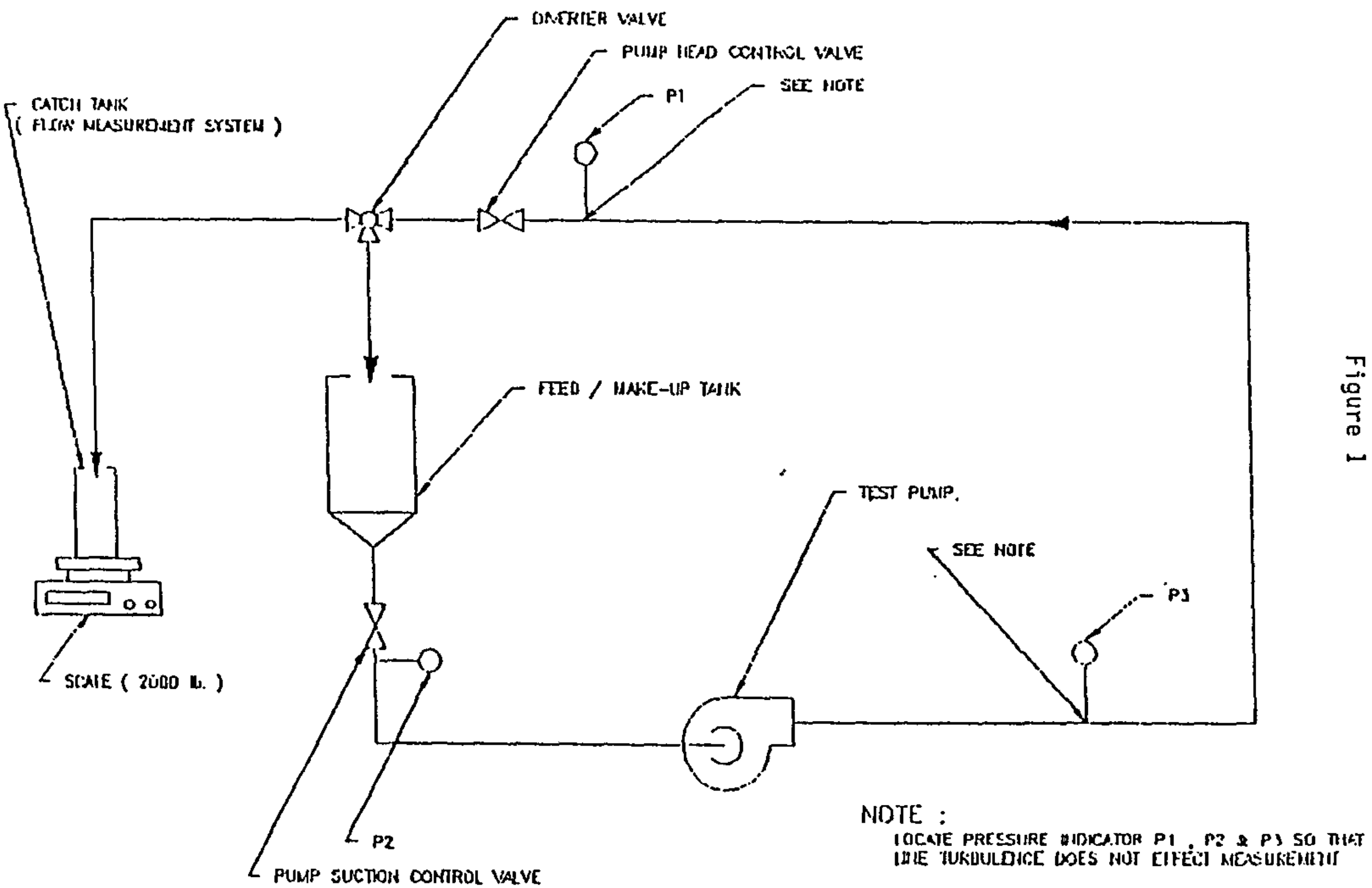

DIVERTER VALVE
PUMP HEAD CONTROL VALVE
P1
SEE NOTE
CATCH TANK
(FLOW MEASUREMENT SYSTEM)
FEED / MAKE-UP TANK
TEST PUMP.
SEE NOTE
P3
SCALE (2000 lb.)
P2
PUMP SUCTION CONTROL VALVE
NOTE :
LOCATE PRESSURE INDICATOR P1 , P2 & P3 SO THAT
LINE TURBULENCE DOES NOT EFFECT MEASUREMENT

Figure 1

To ensure the validity of testing, that it relates with other seller testing, and to ensure a statistical value to the test, each of the tests should be done a minimum of three times.

6.0 MANPOWER REQUIREMENTS

The seller shall provide all equipment, material (except simulant), SINE factory engineer for on site test support and other manpower as required to perform the testing program.

Westinghouse Hanford personnel will observe the testing and act as witnesses for data verification and will record test activities using a video camera and photographic equipment.

7.0 REPORTING

A data summary for the feature testing shall be compiled by the seller in support of test activities. The data summary shall be in the form of a letter report. The summary shall include all parameter data requested in support of this test, as well as any observations witnessed during testing. Additional information within the summary should be limited to general notes discussing test outcome, suggestions for improvement and test conclusions. The limited scope of the feature testing does not require a full, in-depth test report.

Data included in the report shall also be accompanied by the method by which the value was obtained, i.e., direct measurement, calculation (include equation), etc. The accuracy of the recorded data shall also be included.

8.0 SAFETY

The seller shall ensure that all activities pertaining to the preparation, completion, and disposition of these activities shall be in accordance with local, state, and federal codes, regulations, and guidelines.

9.0 MILESTONES

Activities	Commitment Date	Responsible Organization
Test Procedure Submittal	August 3	Seller
Ship Simulant to seller	August 10	Westinghouse Hanford
Test Procedure Approval	August 10	Westinghouse Hanford
Start Testing	August 20	Seller
Finish Testing	August 31	Seller
Data Summary Submittal	September 7	Seller
Ship Simulant to Westinghouse Hanford	September 7	Seller
Data Summary Approval	September 14	Westinghouse Hanford

All activities pertaining to this statement of work must be completed on or before September 14, 1990.

APPENDIX B

WATER/AIR SCARIFIER

STATEMENT OF WORK

STATEMENT OF WORK
FOR
HIGH PRESSURE WATER/AIR SCARIFIER FEATURE TESTS

1.0 INTRODUCTION

Investigations have identified several methods for the removal and decontamination of radioactive and hazardous wastes from 149 single-shell waste tanks located at the Hanford Site in southeastern Washington state.

One of the potential methods identified is a commercially available water jet cleaner/scarifier which possesses a vacuum type debris removal system (see Figure 1). The possible use of high pressure air as a substitute for water has also been identified for investigation.

This document discusses and defines tasks to be completed in support of the testing and evaluation of water jet cleaner/scarifiers, air jets, and depending upon air jet success, air jet cleaner/scarifiers. The results of these tests will be used in recommending methods of retrieval to be studied as candidates for tank clean-out activities.

2.0 OBJECTIVE

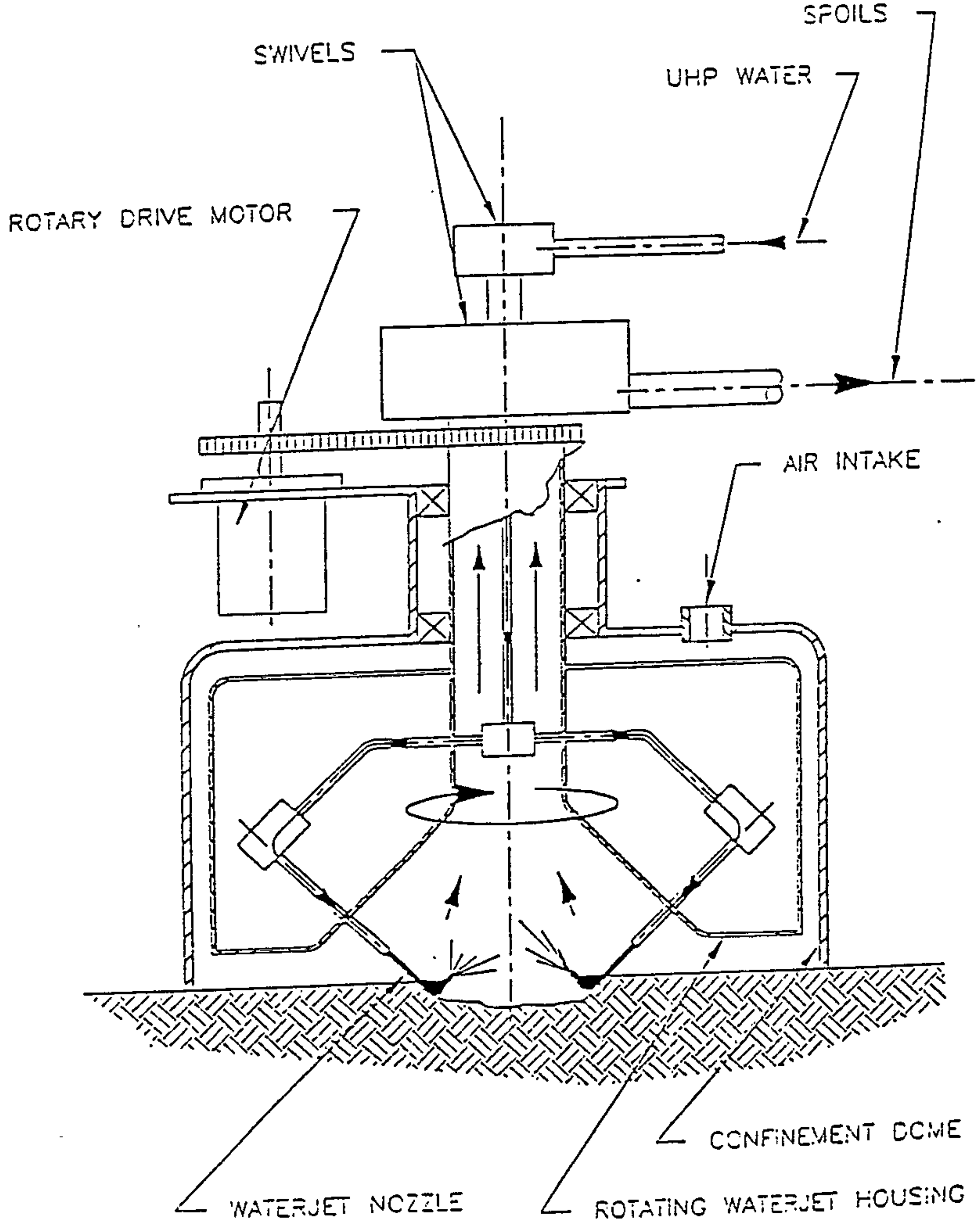
The objective of these tests is to make a judgement whether the tested technologies possess sufficient merit to recommend further investigation. This judgement will be based upon the outcome of several basic tests involving water and air jets and upon the simulant dislodging rates achieved during testing.

A target maximum waste dilution of 1:1 has been chosen for these tests. Any water used to dilute the waste shall be removed in addition to solids removal .

The following areas of high pressure technology will be evaluated:

1. Near sonic velocity water jet cutting of salt cake at high (to 10 kpsi) or ultra-high (10-60 kpsi) pressure. This will be a reference to compare all other tests.

Figure 1. Cleaner/Scarifier.



2. Near sonic velocity air jet cutting of salt cake at high (0.5 - 4 kpsi) pressure. The test would evaluate whether air jet technology is applicable enough to warrant air jet scarifying.

3. Near sonic velocity water scarifying at high (to 10 kpsi) and ultra-high (10-60 kpsi) pressure. The maximum test pressure shall be no less than 30,000 kpsi.

4. If straight line testing of an air jet is deemed successful, air operated scarifier testing shall be evaluated by modifying a commercially available water scarifier for air operation. The same scarifier unit may be used for both series of tests at the vendor's discretion.

3.0 SCOPE

The scope of this task is not to optimize parameters, but to evaluate an "off the shelf" technology's feasibility as a dislodging tool for our waste retrieval task. Air jet investigation is viewed as simple development of high pressure technology as currently applied in water jet operation.

4.0 TEST SIMULANT

4.1 SIMULANT DEVELOPMENT

All testing shall be performed using simulant developed by Westinghouse Hanford Company. The simulants are still in development and may deviate from the target values as indicated.

4.2 SLUDGE SIMULANT

The components of the sludge simulant will be bentonite clay, water, and barium sulfate (a non-toxic, non-hazardous material). The properties of the sludge are as in Table 1.

4.3 SALT CAKE SIMULANT

Two forms of salt cake will be used in this investigation. Type 1 is a hard and dry form similar to low strength concrete. To produce the simulant, a commercial fertilizer, Sulfur K-Mag, or Langbeinite, is mixed with water and allowed to crystallize. Type 2 is a soft, moist material to simulate salt cake saturated in a chemical liquor. As a simulant, another commercial fertilizer, urea, is mixed with water and allowed to crystallize.

TABLE 1

Target Values

Properties	Salt Cake Type 1	Salt Cake Type 2	Sludge	Deviation
Bulk Density (g/ml)	2.0	1.1	1.6	±15%
Shear Force (lbs)	6000	---	---	±40%
Viscosity (cp)	---	---	1.7 million	±15%

4.4 SIMULANT PROVIDED

Approximately 1.3 cubic yards of simulated sludge waste will be delivered in a ready for use form. Due to the material characteristics, the same material may be used for water scarifier tests after air scarifier tests are completed.

Ingredients to make 1.3 cubic yards of each simulated salt cake waste will be supplied by Westinghouse Hanford. The characteristics required for salt cake simulation force new salt cake to be used for each test run. The salt cake must be prepared at the vendor's facility from materials supplied by Westinghouse. The method of waste preparation shall be included as a separate document.

If additional simulant is required, the vendor must identify the additional quantity as part of the bidding process.

4.5 SIMULANT RESPONSIBILITIES

4.5.1 Westinghouse Hanford Responsibilities

Westinghouse Hanford will be the generator of record for the simulant when it is declared a waste product. The simulants will have a Material Safety Data Sheet (MSDS) when shipped. The used test simulant will be reanalyzed before disposal to reaffirm its non-hazardous status.

4.5.2 Vendor Responsibilities

The vendor shall be responsible for the simulants while they are at the test site. This includes assuring that the material is not chemically contaminated or replaced and the MSDS is maintained during this period. If the simulants are altered, Westinghouse Hanford Company will not assume disposal responsibility.

4.6 TRANSPORTATION/CLEAN-UP

The test simulant will be shipped in Department of Transportation (DOT) approved drums to the vendor facility just before testing. Each drum will be labelled with an MSDS.

Additional empty DOT approved drums will be sent for use in repackaging of the test simulant. After testing has been completed, the simulants will be cleaned out of the test equipment. The simulants can not be altered except for the addition of potable water during the clean-up. The total water addition will be limited to doubling the test volume.

The simulant will be repackaged into the containers and shipped by the vendor to a location directed by Westinghouse Hanford. Westinghouse Hanford Company will reimburse the vendor for all incurred shipping costs.

5.0 DESCRIPTION OF TEST

5.1 TEST METHOD

5.1.1 Jet Testing

Air jet testing is intended to allow the vendor and Westinghouse Hanford to assess its characteristics as a technology worthy of feature testing as a scarifier. A single water jet test is to be performed to allow both the vendor and Westinghouse Hanford personnel to observe the general characteristic differences between air and water jet operation.

The test method shall be as simple as possible, using a traversing mechanism to track the jet across a pan of simulant. Displaced simulant removal by a vacuum system is not necessary for these tests. A length of steady state operation, bounded by a test start up and shut down region is required, however. The traversing distance can be minimized for these tests to economize on simulant use.

5.1.2 Scarifier Testing

The test will be performed by attaching the scarifier to a traversing mechanism and guide the assembly across a pan of simulated waste. This method will be used for water jet scarifying. The method will also be used for air jet scarifying, providing previous test outcome is deemed successful.

The traversing mechanism shall be marked with specific start and finish points. The speed of the traversing mechanism shall have variable speed capability and must maintain a set speed.

The product collection system will be separated to allow the solids generated during the beginning and end of the test to be separated from the steady state portion of the test. Valving will separate and channel product into the desired drum. The material removal rate will be calculated from solids removed during steady state operation.

The test will begin by activating the vacuum system, scarifier, and traversing mechanism. The debris will be routed to the "end effects" drum. As the traversing mechanism passes the start point, a stop watch is activated, and the valving turned to route product to the measured collection drum. At the point where the finish point is reached, the stop watch is stopped and the valving is returned to its original position, routing material to the "end effects" drum. The system then continues moving through the sludge until the system can be shut down.

In this method, test end effects are separated from steady state operations and actual system capacity can be measured. The length of traversing, at steady state conditions, should be at least 5 feet. The test simulant pan size should be sized from this criteria and from the number of tests foreseen.

5.2 TEST SET UP

5.2.1 Linear Testing

The test set up for air jet testing shall be determined by the vendor.

5.2.2 Scarifier System

The test apparatus should be constructed as in Figure 2. If an alternative test setup is advised, a description shall be included in the bid proposal.

5.3 RECORDED PARAMETERS

The following values will be recorded during the feature testing:

- Jet water/air pressure (The measuring location shall be the same for all tests and shall be as near the nozzle as practical.)
- Jet water/air flow rate
- Jet water/air nozzle orifice size
- Scarifier vacuum airflow rate, SCFM (this may be calculated from pump data if necessary)
- Vacuum pressure at the scarifier
- Water/air jet angle
- Traversing rate
- Waste removal rate (as measured)
- Nozzle to work distance
- Scarifier to work distance

5.4 FEATURE TESTS

The feature tests shall be as follows. They shall be repeated for waste Types 1 and 2 salt cake and for sludge. Each test shall be repeated to verify its results.

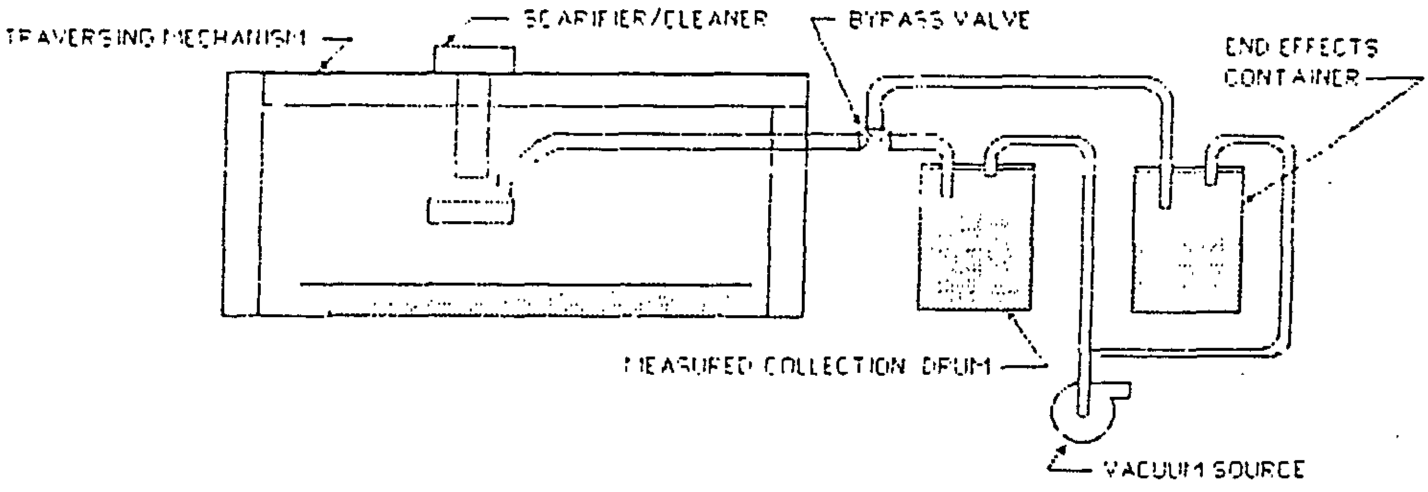
5.4.1 Jet Cutting Tests

1. Test a water jet on a horizontal pan of simulant. The test parameters shall be chosen by the vendor. Additional tests include variations of jet angle in a single waterjet using the optimum parameter from the feature testing.

2. Test the air jet on a horizontal pan of simulant. The test parameters shall be chosen by the vendor. Additional tests include variations of jet angle in a single waterjet using the optimum parameter from the feature testing.

3. The air nozzle will be redesigned based upon results from Test #2, particular concern exists for the higher pressure range. Tests specified in #2 will be reperformed on each material type.

Figure 2. Proposed Product Collection Layout.



5.4.2 Scarifier Tests

1. Test a water scarifier on horizontal pan. The initial parameters shall be chosen by the vendor.

Providing Test 1 is considered successful, the following tests are performed:

2. Test an air scarifier on a horizontal pan with test parameters as chosen by the vendor.

As the final test for each waste type, the simulant will be completely removed by the scarifier. Water or air shall be used, depending upon previous feature test outcome. The parameters will be as recommended by the vendor.

All tests shall be witnessed by Westinghouse Hanford personnel.

5.5 TEST EQUIPMENT

The following items are required for test completion. Unless otherwise specified, they will be provided by the vendor. Other items may be required and their acquisition shall be the responsibility of the vendor.

- The scarifier unit shall be controlled by a traversing mechanism. Although one axis must be controlled for traversing speed, the second needs only to be adjustable to maintain the desired equipment to work distance from the waste. If one pan is used to perform several tests on the same simulated waste block, the ability to offset the scarifier or maneuver the pan underneath the scarifier will be required.

- The simulated waste pan shall have sides with a 45 degree angle slope. The pan shall be 3 inches deep. The sloped sides are necessary due to the expansion characteristics of the salt cake curing process and may also aid removal efforts. The length and width of the pan(s) shall be sized to conform to the tests described. See Section 5.1.

  The length, width or the number of pans required will be subject to the vendor's discretion. Due to time constraints, all salt cake of a single type must be poured at the same time. This disallows the pan(s) from being reused for further tests of the same type material, although the pans may be reused for involving other simulant types.

- The system shall be arranged so that the product (dislodged solids and water, if used) is deposited in a 55-gal drum or other container. The product stream shall also have at least two flow paths, arranged so product flow may be routed from one drum to another during test operation. Arranged properly, the product collected during test start up and shut down may be routed to a different collection drum. This would isolate product collected when test parameters, such as traversing rate or water flow, are unstable. See Figure 3.

- As discussed previously, a mixer will be required for salt cake waste preparation. Equipment to spread out the material will also be needed.

6.0 MANPOWER REQUIREMENTS

The vendor will provide all equipment, material (except simulated waste), and manpower to perform the testing program.

Westinghouse will observe the testing and act as witnesses for data verification.

The vendor will record test activities using a video camera and photographic equipment. An unedited copy of both photographs and video recordings shall be made available to Westinghouse Hanford upon request.

7.0 REPORTING

A data summary for the feature testing shall be compiled by the vendor in support of test activities. The data summary shall be in the form of a letter report. The summary shall include all parameter data requested, as well as any observations witnessed during testing. Additional information within the summary should include general notes discussing test outcome, suggestions for improvement, and test conclusions.

Data shall also be accompanied by the method by which the value was obtained. i.e. direct measurement, calculation (include equation), etc. The accuracy of the recorded data shall also be included.

A simple sketch, depicting the average simulant cross-section after jet or scarifier operation, shall be made for each feature test. The sketch shall include the depth of removal, the width of removal, and the depth of material dislodged , but not removed by the vacuum system. A photograph will also be made.

8.0 SAFETY

The vendor will ensure that all activities pertaining to the preparation, completion, and disposition of these activities shall be in accordance with local, state, and federal codes, regulations, and guidelines.

9.0 SCHEDULE

All testing shall be complete by October 19, 1990. Westinghouse Hanford shall receive the data summary from the vendor by October 26, 1990.

Activities	Duration Work Days	Responsible Organization
Contract Award to Test Procedure Submittal	7/06/90	Vendor
Contract Award to Shipping Simulant	6/29/90	Westinghouse Hanford
Procedure Submittal to Procedure Approval	7/20/90	Westinghouse Hanford
Procedure Approval to Start Testing	8/24/90	Vendor
Start Testing to Finish Testing	10/19/90	Vendor
Start Testing to Issue Interim Test Report	9/14/90	Westinghouse Hanford
Finish Testing to Data Summary Submittal	10/26/90	Vendor
Finish Testing to Shipping Simulant	10/26/90	Vendor
Data Summary Approval	11/09/90	Vendor

APPENDIX C

AIR CONVEYANCE SYSTEM

STATEMENT OF WORK

1.0 INTRODUCTION

Investigations have identified several methods to perform the removal of wastes from 149 single-shell waste tanks located at the Hanford Site in southeastern Washington state. The investigations were further divided to separate dislodging techniques from conveying techniques.

This document discusses and defines tasks to be completed in support of the testing and evaluation of an air conveyance system. An air conveyance system uses rapidly moving air, as in a vacuum cleaner, to impart momentum onto the feed material. The feed is therefore conveyed by the moving air. This document shall refer to the air conveyance system as the "conveyance system."

2.0 OBJECTIVE

All feature testing shall be performed on one conveyance system. The objective of these tests are to evaluate the mechanism's ability to convey 10 gpm of simulated sludge waste and evaluate the conveyance system's operability at elevation differences up to 50 feet.

3.0 SCOPE

The scope of this task is not to optimize parameters, but to evaluate an "off the shelf" technology's feasibility as a conveying tool for our waste retrieval task.

4.0 TEST SIMULANT

4.1 SIMULANT DEVELOPMENT

All testing shall be performed using simulant developed by Westinghouse Hanford Company.

4.2 SLUDGE SIMULANT

The components of the sludge simulant will be bentonite clay, water, and barium sulfate (a non-toxic, non-hazardous material). The properties of the sludge are a below:

Properties	Target Values	Deviation
Bulk Density (g/ml)	1.6	±15%
Viscosity (cp)	1.7×10^6	±15%

4.3 SIMULANT PROVIDED

Westinghouse Hanford will provide 6 30-gal drums of simulated sludge waste.

4.4 SIMULANT RESPONSIBILITIES

Westinghouse Hanford will be the generator of record for the simulant. The simulants will have Material Safety Data Sheets (MSDS) and will be classified as non-hazardous when shipped. The used test simulant will be reanalyzed before disposal to reaffirm its non-hazardous status.

4.5 TRANSPORTATION/CLEAN-UP

The test simulant will be shipped in Department of Transportation (DOT) approved drums to the test facility just before testing. Each drum will be properly labelled.

Additional empty DOT approved drums will be sent for use in repackaging of the test simulant. After testing has been completed, the simulants will be shipped back to the Chemical Engineering Lab for disposal of the simulant. The simulants cannot be altered except for the addition of potable water during the clean-up. The total water addition will be limited to doubling the volume of simulant originally sent to the test site.

4.6 TEST RESPONSIBILITIES

Remote Systems Engineering will be responsible for conducting all testing, operation/maintenance of equipment, data recording and clean up of simulant. Remote Systems Engineering will also provide for moving the equipment and simulant to and from the test site.

The FMEF Facility Operations Personnel will be responsible for providing the JCS work package and procedure, a person in charge (PIC) to oversee the testing program, and miscellaneous equipment required for testing, such as: stop watch, shovels, hard hats, water hose, hearing protection, and safety glasses. They will also provide general logistics support during testing.

5.0 DESCRIPTION OF TEST

5.1 TEST LOCATION SPECIFICATIONS

A desirable test condition is to simulate underground tank operations and evaluate the conveyance system by pumping from an elevation at least 50 feet below the conveying equipment location.

The location for this test will be in the FMEF Bldg. 427 in the 400 Area of the Hanford Site. See Figures 1 through 4 for general equipment locations. Equipment access to the building should be through the truck lock (325 B), on elevation 0 ft-0 in. See Figure 1.

The air conveyance equipment package will be transported to the 42 ft 6 in. elevation, crane bay, via the service elevator (100) (see Figure 2). The equipment should be located close to the rail to facilitate the hose drops to the 0 ft-0 in. and -17 ft-6 in. elevations (see Figures 2 and 3).

The drums of simulant will be positioned at one of two locations depending on the desired test conditions at the time. They will be moved between the 0 ft-0 in. elevation floor near hatch #3 and the -17 ft-6 in. elevation on hatch #2 (see Figures 1 and 3).

5.2 TEST SET-UP

Requirements for the conveyance equipment are as follows (see Figure 4):

- The blower shall be downstream of the primary solids separation system.
- The blower capacity should be sized (see Section 2.0) to convey a minimum of 10 gal per minute of sludge through an elevation change of at least 50 ft.

The test set-up shall be determined by Westinghouse Hanford Company engineering, but is anticipated to essentially be as in Figure 4.

The test set-up shall have as a minimum:

- The average conveying rate (calculated by time vs. volume)
- Measure the elevation (direct measurement with tape)
- Measure the feed to inlet nozzle distance for maximum pick-up by visual estimate

5.3 MEASURED PARAMETERS

The following parameters will be measured during feature testing:

- Average material conveyance rate (calculated)
- Conveying elevation (direct measurement)
- Feed profile - including material type, consistency, physical appearance, etc.
- Product profile - as described above
- Distance of inlet nozzle to sludge for maximum conveying rate (visual estimate)

5.4 TEST METHOD

The test program shall be divided to investigate three areas. The tests required to complete the investigations shall be repeated at least once to ensure data accuracy.

Area 1. Measure the maximum inlet nozzle to feed distance while conveying.
Area 2. Measure the effect of elevation on the maximum conveying rate. At least three elevations will be tested. The elevations shall be 42 ft-6 in., 60 ft-0 in., and 0 ft-0 in.
Area 3. Inspect and measure the buildup of solids on the inner walls of the conveying pipe and primary solids separation system.

Prior to testing, the conveyance piping and the primary separations system shall be disassembled for inspection and to take "before" pictures. The equipment shall be disassembled at least one more time during testing to appraise solids buildup and to collect a solids sample. At the conclusion of the testing, the conveyance piping and the primary separations system will be disassembled to observe the buildup of solids. A sample from the pipe walls, from the separation system, and from the feed shall be gathered. The hold-up in the conveyance system will then be estimated. The conveyance system shall then cleaned out.

5.5 TEST PROCEDURE

1. Fill out the data sheet header.
2. Record the density of the simulant. Give a brief description of the simulant.

3. Record the volume of the simulant in the drum and its weight.
4. Start and run the equipment in the static condition, record any abnormal observations.
5. Record the vacuum in static condition.
6. Record the pressure difference across the filtration system if available via existing gauge.
7. Record the air velocity in the conveyance hose (static condition from vendor specifications).
8. Record the elevation at which conveyance will be tested.
9. Record the identification number of the drum to be tested.
10. Begin conveying the undisturbed simulant from the drum. Make qualitative observations and record start and stop times on data sheet.
11. If undisturbed simulant does not feed, mix simulant to facilitate pick-up. Record all start and stop times when conveying.
12. Determine the optimum distance between the simulant and the conveying hose for maximum conveyance. Visually estimate and record this distance.
13. When best conditions for conveying are established, convey a complete drum. Record the elapsed time for complete conveyance of a drum on the data sheet.
14. If during any phase of conveyance testing a high vacuum reading is encountered, stop conveying, secure equipment, inspect pick up hose, and record observations. Restart equipment and convey potable water until the hose is clear and the vacuum returns to the normal range, record all observations. Continue conveying until drum is empty. Record all stop and start times.
15. At the completion of conveying a complete drum of simulant secure the equipment and inspect the hose and the filtration system and record qualitative observations.
16. Go to the next elevation and repeat steps 8 through 15.
17. Go to the last elevation and repeat steps 8 through 15.
18. Lower the conveying equipment down to zero elevation. Lay the 50 ft of conveyance hose on the ground with tight bends throughout.
19. Convey undisturbed simulant through the hose to determine if it will plug.
20. Record the time taken for the simulant to plug the hose.
21. Disassemble and inspect the conveyance piping.
22. Spray water in the hose if necessary to clear the plug. Once the plug is cleared then potable water should be conveyed to clean the hose out thoroughly.
23. At the completion of conveying testing record any additional observations and make a qualitative summary.

6.0 MAINTENANCE AND CLEAN-UP

There will be a one day training program conducted by a factory trained technician on the operation and maintenance of the rented conveying equipment. At the completion of the testing the simulant will be returned to the Chemical Engineering Lab in the 200E area of the Hanford Site for disposal. The conveying equipment will be cleaned-up prior to its return to the vendor.

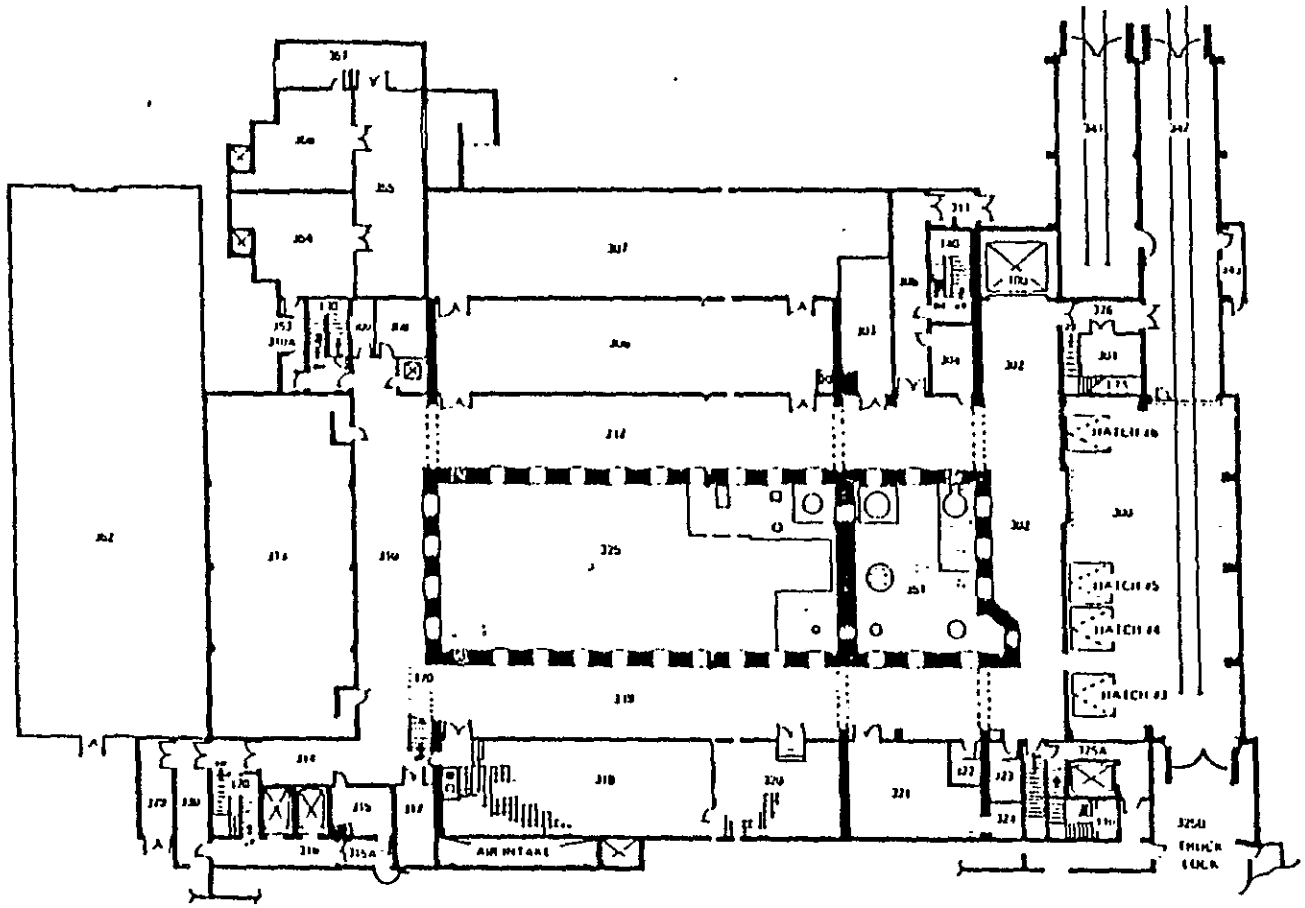
7.0 SAFETY

The nature of this test requires that the test personnel wear safety glasses and hard hats. Test personnel will be required to have building orientation before the testing begins. Since the equipment used in this test operates at an 85 - 90 dB sound level, hearing protection is required.

8.0 SCHEDULE

Activity	Date
Equipment on site	8/7/90
Equipment at test site	8/8/90
Simulant at test site	8/13/90
Equipment set-up	8/9/90
Operator training	8/10/90
Feature Test	8/13 - 8/17/90
Equipment clean-up	8/17/90
Write draft test report	8/20 - 8/31/90

ENTRY LEVEL FLOOR PLAN



0' 0" ELEVATION

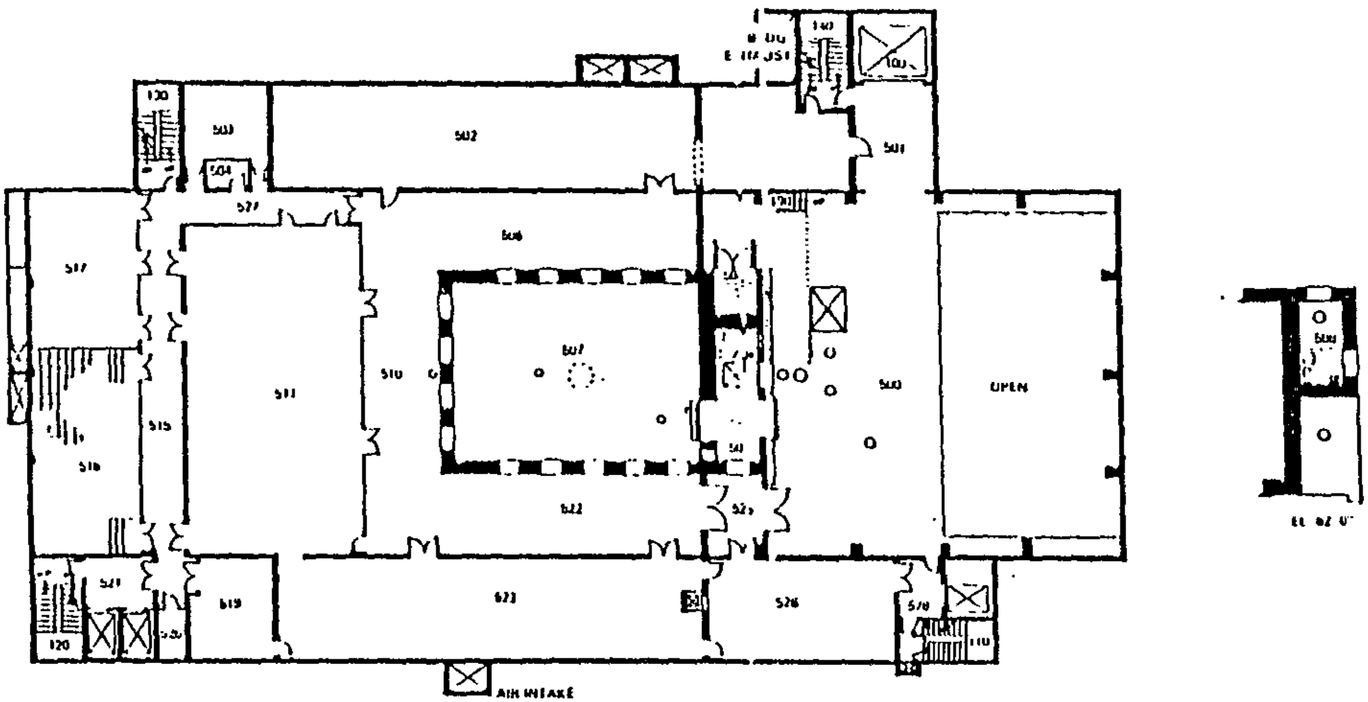
300	SHIPPING & RECEIVING	309	JANITOR'S CLOSET	316	VESTIBULE	325	MAIN PROCESS CELL	351	MAINTENANCE & DECONTAMINATION CELL
301	SOLID WASTE STORE	310	OPERATING CORRIDOR	317	RETENTION WASTE & ANALYSIS	325A	VESTIBULE	352	MECHANICAL EQUIPMENT WING
302	OPERATING CORRIDOR	310A	VESTIBULE	318	OPERATIONS CONTROL ROOM	325B	TRUCK LOCK	353	VESTIBULE
303	FUME HOOD SCRUBBER	311	VESTIBULE	319	OPERATING CORRIDOR	328	DOCK	354	EMERGENCY GENERATOR #2
304	OHP LABORATORY	312	OPERATING CORRIDOR	320	MP CONTROL ROOM	329	VESTIBULE	355	COOLING TOWER
305	VESTIBULE	313	MP CELL ATMOSPHERE EQUIP.	321	CLOSED LOOP COOLING	330	STORAGE	356	EMERGENCY GENERATOR #1
306	EXHAUST FILTER PLENUM	314	VESTIBULE	322	WOMEN'S TOILET	341	LIQUID WASTE LOADOUT	357	VESTIBULE
307	EXHAUST FAN ROOM	315	STORAGE ROOM	323	MEN'S TOILET	342	TRUCK LOCK		
308	HEPA FIRE SYSTEM EQUIPMENT	315A	AIR LOCK	324	SUMP PUMP	343	EMERGENCY EXIT		

HEDL 8408 165.6

Figure 1.

9 1 1 2 7 5 2 0 3 4 5

FUEL FABRICATION LEVEL FLOOR PLAN



+42'-6" ELEVATION

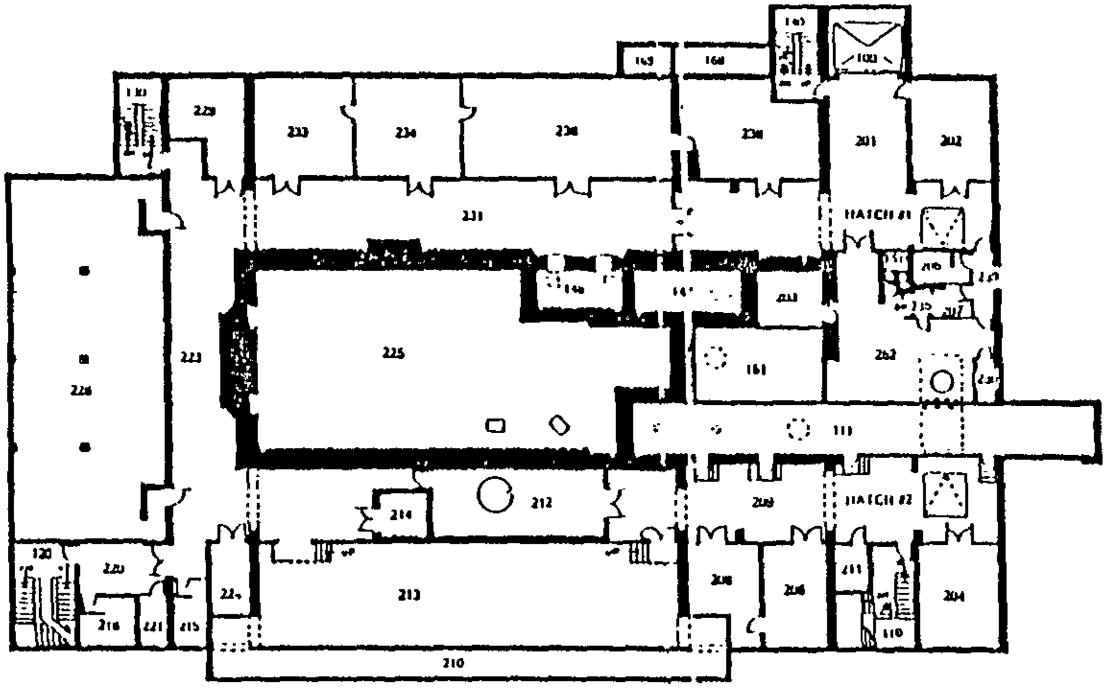
190	STAIR	515	CORRIDOR
500	CRANE BAY	516	PROCESS CONTROL
501	ELEVATOR CORRIDOR	517	FIN WELD & LEAK CHECK
502	RECIRCULATION EQUIPMENT	519	GRINDING
503	OHP LABORATORY	520	PERSONNEL DECONTAMINATION
504	JANITOR	521	VESTIBULE
506	OPERATING CORRIDOR	522	OPERATING CORRIDOR
507	UPPER PROCESS CELL	523	PELLET FABRICATION
508	ENTRY LOCK	525	AIR LOCK
509	TRANSFER LOCK	526	LOW GAMMA RECEIVING
510	OPERATING CORRIDOR	527	PASSAGE
511	PIN LOADING	528	VESTIBULE

HEDL 8408-106.7

Figure 2.

9 1 1 2 5 2 0 6 1 6

EQUIPMENT LEVEL FLOOR PLAN



-17'-6" ELEVATION

201 ELEVATOR VESTIBULE
202 ELECTRICAL SWITCHGEAR
203 OBSERVATION AREA
204 EMERGENCY AIR COMPRESSOR
205 MEN'S TOILET
206 UNINTERRUPTABLE POWER SUPPLY #1
207 WOMEN'S TOILET
208 ELECTRICAL EQUIPMENT ROOM
209 EQUIPMENT CORRIDOR
210 SUPPLY AIR PLENUM
211 COMMUNICATIONS
212 REACTOR ROOM
213 SUPPLY AIR EQUIPMENT
214 REACTOR CONTROL
215 WOMEN'S TOILET
216 MEN'S TOILET
220 AIR LOCK
221 SUMP PUMP
223 EQUIPMENT CORRIDOR
224 MECHANICAL EQUIPMENT
226 MP CELL SUPPORT
229 MP PRESSURE CONTROL TANKS
230 STORAGE
231 EQUIPMENT CORRIDOR
233 ELECTRICAL SWITCHGEAR
234 INCINERATOR OFF-GAS
235 SUMP PUMP
236 ANALYTICAL CHEMISTRY EXHAUST EQUIPMENT
238 VACUUM EQUIPMENT
239 PASSAGE
252 SUSPECT EQUIPMENT REPAIR

HEDL 8408 185.6

Figure 3.

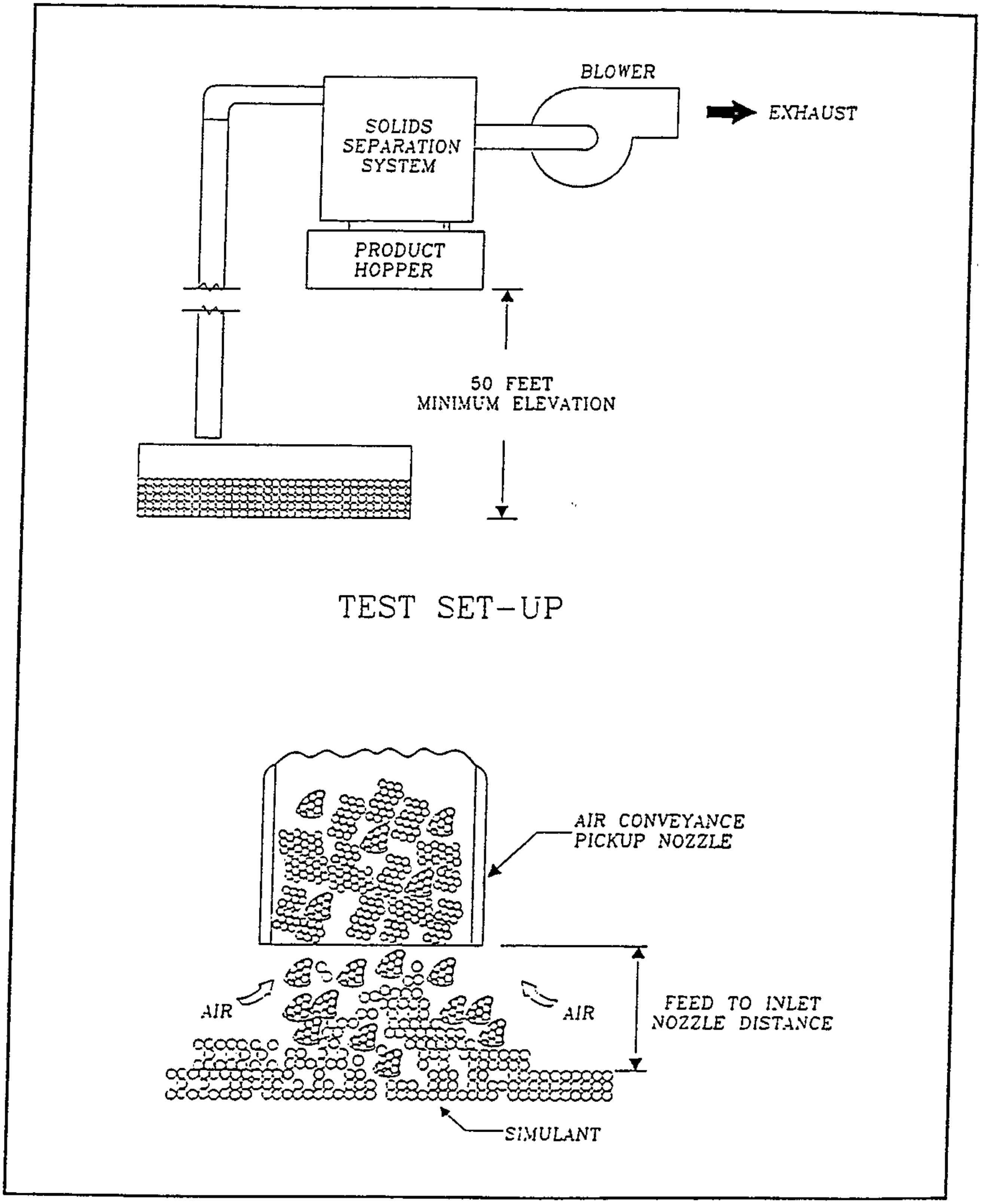

BLOWER
EXHAUST
SOLIDS
SEPARATION
SYSTEM
PRODUCT
HOPPER
50 FEET
MINIMUM ELEVATION
TEST SET-UP
AIR CONVEYANCE
PICKUP NOZZLE
AIR
AIR
FEED TO INLET
NOZZLE DISTANCE
SIMULANT

FIGURE 4

DATA SHEET

Page ___ of ___

TEST ENGINEERS:____________________ DATE:____________________

____

SIMULANT VOLUME:____________________(PER BARREL)

SIMULANT WEIGHT:____________________(PER BARREL)

SIMULANT DENSITY:____________________

DESCRIPTION OF SIMULANT:____

____

____

STATIC CONDITION:

VACUUM (MANUFACTURERS SPECS):____________________

SCFM THROUGHPUT (MANUFACTURERS SPECS):____________________

OBSERVATIONS IN STATIC CONDITION:____________________________________

____

____

____

____

DATA SHEET

Page ___ of ___

CONVEYANCE OF SIMULANT:

CONVEYING ELEVATION:___________________________

	1	2	3	4	5	6
START						
STOP						

	7	8	9	10	11	12
START						
STOP						

TOTAL TIME:________________________ TOTAL VOLUME:___________________________

AVERAGE CONVEYING RATE:___________________________________ GPM

OBSERVATIONS:____

DATA SHEET

Page ___ of ___

CONTINUATION DATA SHEET:

DATA SHEET

Page ___ of ___

GENERAL TEST SUMMARY: ____________________

A P P E N D I X   D

TEST PROCEDURE

PNEUMATIC NEEDLE SCALER

1.0 INTRODUCTION

The removal of nuclear waste from 149 single-shell tanks on the Hanford Nuclear Site requires investigation into different methods to remove salt and sludge type materials. One of the potential methods for removing salt from the tank walls is a pneumatic needle scaler. The scaler will also be tested for its volume removal capabilities.

This test will give Westinghouse Hanford the information necessary to evaluate the feasibility of the needle scaler as a method for waste retrieval.

2.0 OBJECTIVES

The following are objectives for the performance of the pneumatic needle scaler:

- Determine the removal rate of salt cake simulant from a simulant pan and a simulant block traversing vertically and horizontally.
- Run the scaler on a metal surface and note the effect on both the scaler and the metal.
- Break up salt cake simulant under a layer of sludge.

3.0 SCOPE

The scope of this test plan is not to optimize parameters, but to test the feasibility of an "off the shelf" pneumatic needle scaler as a possible method for waste retrieval. The failure of the item does not exclude the method from further investigation.

4.0 DESCRIPTION OF TEST

4.1 TEST ITEM

Pneumatic needle scaler, Jet F-25NS.

4.2 TEST LOCATION

Westinghouse Hanford, Chemical Engineering Lab.

4.3 EQUIPMENT AND FACILITIES

The simulants to be used for testing the scaler are:

- Salt cake simulant - two pans, Sodium Nitrate base
- Salt simulant block - K-Mag
- Small piece of carbon steel
- Bentonite sludge - 1 gal

5.0 TEST PROCEDURE

5.1 PROCEDURE SUMMARY

The following tests will be performed on the salt cake simulant:

1. The scaler will be run over each simulant three times. The following items will be measured on each run: amount of material removed, length of traverse, average width of the traverse, and the time for the traverse.

2. The scaler will be run vertically into each simulant three times. The following items will be measured on each run: amount of material removed, the depth of penetration, and the time elapsed.

The remaining tests are qualitative:

3. The scaler will be run on the surface of a piece of steel. Its effects on the steel will be noted.

4. The pins of the scaler will be submerged in sludge to determine if it operates under such conditions.

5. Sludge will be applied to the surface of the salt simulant and the scaler run across it to observe material removal.

5.2 TEST METHOD

The pneumatic needle scaler will be run with 90 psi in a 3/8 in. line. The scaler has 19 pins that cycle in and out. It was originally designed for removing slag from arc welds. The scaler will be run across and into the surface of the various simulants to observe material removal and effect on the scaler. The amount of time that the scaler is in contact with the material for each traverse will be recorded. During a traverse the scaler can be lifted from the material to continue scaling. The material removed will be measured by weighing the simulant that is left after scaling. This weight will be compared to the original weight of the simulant to obtain the amount of material removed. The entire test procedure will be video recorded to observe the qualitative aspects of the test plan.

5.3 PROCEDURE

1. Fill out the data sheet header.
2. Record the scaler pin material.
3. Record the density of the simulant.
4. Give a brief description of the simulant.
5. Record the gross weight of the simulant to be tested.
6. Run the scaler across the simulant attempting to remove as much material as possible. The scaler can be lifted from the simulant surface to continue the traverse.
7. Record the total time for the traverse. The time measured for the traverse only includes the time that the scaler is in contact with the simulant.
8. Dump the loose simulant into its appropriate receptacle.
9. Weigh the simulant that is left. The difference between the before and after measurement of the simulant will be the amount of material removed.
10. Measure the total length of traverse in inches.
11. Make qualitative observations about the particle size of the material removed.
12. Repeat steps 5 through 11 two times.
13. Repeat steps 3 through 12 for the salt block simulant.
14. Record the weight of the simulant.
15. Run the scaler vertically into the simulant without traversing.
16. Record the total time for the vertical penetration.
17. Dump the loose simulant.
18. Weigh the simulant that is left.
19. Note the depth of the material removed.
20. Repeat steps 13 through 18 five times.
21. Repeat steps 13 through 19 for the salt block simulant.

22. Submerge the needles of the scaler in sludge simulant to determine if it will breakdown under these conditions. (Qualitative)
23. Apply an inch of sludge to the surface of the salt simulant and run the scaler over and into it to determine the effectiveness of the scaler under such conditions. (Qualitative)
24. Run the scaler on the surface of a piece of steel and observe the effects (Qualitative)
25. Record any observations.

6.0 MAINTENANCE AND FAILURE

Only one scaler will be available for testing. The scaler pins could possibly fail before testing is complete. If the pins do fail then they should be replaced and testing should continue. The failure of the test item does not exclude the method from further investigation.

7.0 SAFETY

This test will produce air born hazardous materials. Therefore, the tests will be performed under a fume hood. The test technicians will be required to wear face shields, protective glasses, respirators, and appropriate clothing.

8.0 SCHEDULE

The total time for testing should be five days.

DATA SHEET

Page 1 of 10

TEST ENGINEERS: ____________________

____

TEST ITEM: NEEDLE SCALER JET F-25NS

DATE: ____________________

PIN MATERIAL: ____________________

SLUDGE VISCOSITY: ____________________

BLOWS/MINUTE: 4,000

SCALING AREA: ____________________

STROKE DISTANCE: .875 in

STEEL COMPOSITION: ____________________

SIMULANT DENSITY: ____________________

SIMULANT COMPOSITION: ____________________

SIMULANT DESCRIPTION: ____________________

____

	TEST RUN NUMBER 1	2	3
WEIGHT BEFORE (lbs)			
WEIGHT AFTER (lbs)			
LENGTH OF TRAVERSE (in)			
AVERAGE WIDTH OF TRAVERSE (in)			
TOTAL TIME FOR TRAVERSE (sec)			

DATA SHEET

NOTES AND OBSERVATIONS:

DATA SHEET

SIMULANT DENSITY:____________________

SIMULANT COMPOSITION:____________________

SIMULANT DESCRIPTION:____________________

____

SIMULANT	TEST RUN NUMBER				
	1	2	3	4	5
WEIGHT BEFORE (lbs)					
WEIGHT AFTER (lbs)					
DEPTH OF TRAVERSE (in)					
TOTAL TIME FOR TRAVERSE (sec)					

DATA SHEET

NOTES AND OBSERVATIONS:

DATA SHEET

SIMULANT DENSITY:____________________

SIMULANT COMPOSITION:____

SIMULANT DESCRIPTION:____

	TEST RUN NUMBER		
	1	2	3
WEIGHT BEFORE (lbs)			
WEIGHT AFTER (lbs)			
LENGTH OF TRAVERSE (in)			
AVERAGE WIDTH OF TRAVERSE (in)			
TOTAL TIME FOR TRAVERSE (sec)			

DATA SHEET

NOTES AND OBSERVATIONS:

DATA SHEET

SIMULANT DENSITY:________________

SIMULANT COMPOSITION:________________

SIMULANT DESCRIPTION:________________

____

SIMULANT	TEST RUN NUMBER				
	1	2	3	4	5
WEIGHT BEFORE (lbs)					
WEIGHT AFTER (lbs)					
DEPTH OF TRAVERSE (in)					
TOTAL TIME FOR TRAVERSE (sec)					

DATA SHEET

NOTES AND OBSERVATIONS:

DATA SHEET

COMMENTS ON THE AFFECT OF SLUDGE ON THE SCALER:

OBSERVATIONS OF THE SCALER IN SLUDGE AND SALT:

DATA SHEET

OBSERVATIONS OF THE SCALER ON STEEL: